Journal of the Royal Society of Western Australia, 98: 139–140, 2015

Biogas for Sub-Saharan Africa: Current situation and opportunities for improving dissemination

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Biogas technology has the potential to improve energy access and waste management practices in both urban and rural Sub-Saharan Africa (SSA), along with making a positive contribution to health and the environment. The last seven years have seen a significant increase in the uptake of domestic biogas systems in a selected number of SSA countries through the Africa Biogas Partnership Programme (ABPP). Before ABPP, biogas dissemination has been slow and sporadic in the region, and even today much of the potential is still untapped. One barrier has been the focus on a selected few biogas systems that use cattle dung as their main feedstock. This paper will provide key recommendations on how biogas dissemination in SSA can be improved, and highlight the energy production potential from a range of feedstocks. A proposed biogas system model will be introduced which could become a valuable tool for identifying optimal biogas system designs for particular applications in SSA.

The livelihoods of millions of households in Sub-Saharan Africa could be significantly improved by biogas technology providing an alternative fuel for cooking and lighting. The majority of SSA households, particularly in rural regions, currently rely on traditional biomass sources including firewood, charcoal, cattle dung, and crop residues for cooking. Traditional cooking stoves are inefficient and produce indoor pollution, which causes a number of lung, and some heart diseases. Furthermore, the collection of firewood contributes to deforestation, land degradation, aggravated soil erosion, and flooding. Biomass collection can also be dangerous for women and children who often carry out the work, and takes away time from other important activities, including attending school. Biogas technology harnesses the anaerobic digestion process to convert organic waste into biogas and a nutrient rich effluent that is suitable as fertiliser. Biogas is a mixture of 50–70% methane, 30–45% carbon dioxide, as well as containing other trace gases, which can be used like natural gas for cooking, heating, electricity, and as a vehicle fuel. Biogas use in SSA not only provides an alternative cooking fuel, but also provides fertiliser and an effective method of treating organic waste. For example, household biogas systems are amenable of the connection of a latrine for improved sanitation.

Dissemination of biogas technology in SSA has been sporadic since its first introduction in the 1950s. Domestic biogas programmes operating under ABPP are currently limited to Burkina Faso, Ethiopia, Kenya, Tanzania and Uganda. The most common type of biogas system used in these programmes are fixed dome digesters, with some plug flow and floating cover digesters also being installed. The main barriers hindering larger dissemination include high installation costs, inadequate user training, insufficient servicing, and inappropriate designs. Poor design choices, mainly due to overlooking the user energy needs and local conditions, contribute to the short lifespan of many installed biogas systems. The key recommendation for improving biogas dissemination is improving the design choices of biogas systems. This requires modifications to be made to existing system designs to suit the context and needs of the intended user. Technical considerations such the surrounding environmental conditions, technical skills, and materials available, along with the socio-cultural context and needs of the user, need to be included in the system design. Experience in parts of SSA and other developing regions has shown that collaboration between research institutions, governmental departments and potential as well as current biogas users helps increase its dissemination. Such collaboration can include establishing knowledge sharing hubs for biogas technology to ensure the technology continues to be developed and applied more efficiently and appropriately.

The total estimated methane production potential from suitable biogas feedstocks in SSA is 23.7 billion m^3/year and 245,600 GWh of energy. Suitable biogas feedstocks include livestock manure, livestock food waste (eggs, hides and skin, and milk), crop waste normally burnt, crop equivalent food waste, domestic sewage, and the organic fraction of municipal solid waste (MSW). Crop waste normally burnt and crop equivalent food waste make up the majority of the potential, with 43% and 26% of the total, respectively. Given that current domestic biogas programmes in SSA focus on cattle manure as the main feedstock, this highlights the opportunity to improve waste management practices through harnessing the other abundant organic waste streams in biogas systems. It is therefore recommended that biogas dissemination programmes in SSA extend their scope to include a wider variety of feedstocks, particularly food and crop wastes.

This research aims to address the gap in appropriate designs of biogas systems through the development of a biogas system design model that identifies optimal designs for particular applications in SSA based on user defined priorities of sustainability criteria. Development of the biogas system design model requires identification of the essential parameters that influence biogas production and digester design, a review of biogas technologies applicable to SSA, assessment of feedstocks

* Extended abstract of a paper presented at the Royal Society of Western Australia Centenary Postgraduate Symposium 2014 held at The University of Western Australia on 3 October 2014.

available and selection of appropriate sustainability criteria. The parameters included in the model and considered essential in the design of biogas systems are: fertiliser and energy requirements; feedstock (type, amount, and rate of supply); water supply; land area available for installation; climate (ambient temperature and rainfall) and the construction materials available locally. Six main types of biogas digesters have been identified for the model, including batch reactor, continuously stirred tank reactor (CSTR), fixed dome digester, fixed film digester, floating cover digester, and plug flow digester. A wide range of feedstocks are considered, including crop residues, livestock manure, MSW, food waste, and domestic wastewater. The sustainability criteria that can be ranked by the user according to priority in the model are environmental impact, cost, social contribution, ease of operation, reliability and robustness, as well as technical efficiency. Multi-criteria decision-making methods are applied in the model to identify the optimal biogas system design based on the priority rating of the criteria and the system designs that are feasible according to the main parameters. The biogas system design model presented in this paper empowers potential biogas users in SSA to realise the energy and biogas technologies that could be available to them to treat their organic wastes.